THAT Corporation

Department Engineering

Subject **More Analog Secrets Your Mother Never Told You**

Name THAT Corporation

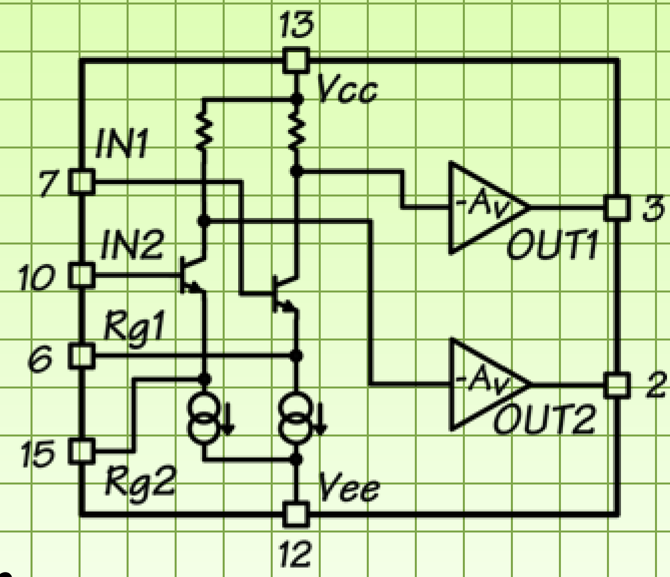
Address 127th AES Convention
New York, Oct 2009

Agenda – Focus on Mic Preamps

- THAT1570 – new analog mic preamp
- Phantom power switching
- Phantom power protection
- RFI protection
- Input pads & line inputs
- Output stages for mic preamps
- Prizes – stick around!

New! THAT1570 Spec Summary

- Low Noise:
  - 1 nV/√Hz EIN (60 dB gain)
    -134.8 dBu (20kHz BW)
  - 18.5 nV/√Hz EIN (0 dB gain)
    -109.4 dBu (20kHz BW)
- Low THD+N:
  0.0003% <30 dB gain
  0.0008% @ 40 dB gain
- Low Current: 7.5 mA typ
- Wide BW: 4.2MHz @ 40 dB gain
- High Slew Rate: 53 V/µs
- Wide Signal Swing: >28.7 dBu (±18V supplies)
- Gain adjustable from 0 to > 60 dB
- Differential output
- Small 4 x 4 mm QFN16 package

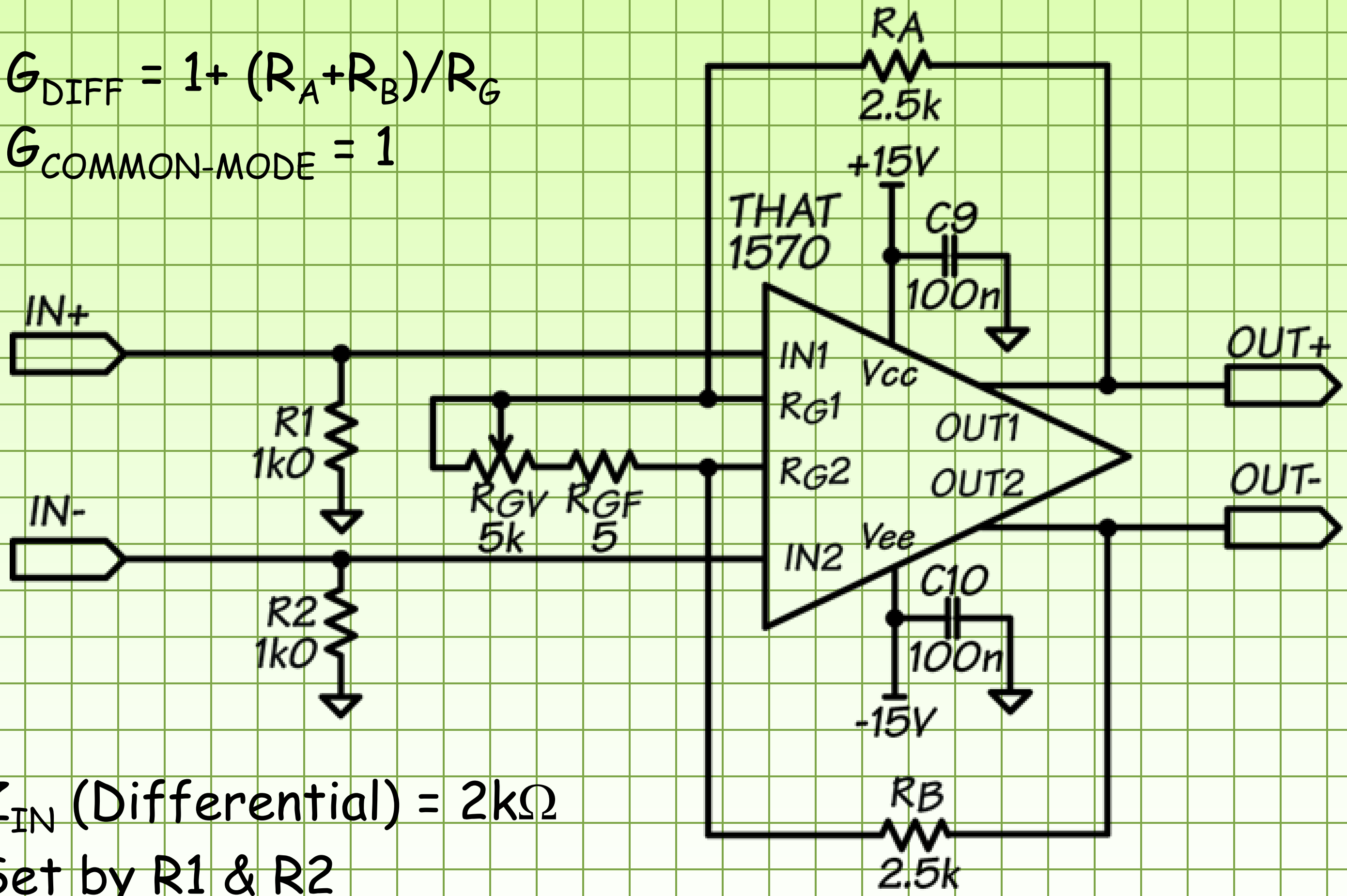


THAT1570 Features

- External R_F (R_A and R_B) allows impedances to be optimized
- Lowest noise monolithic audio preamp available today
- Extremely high dynamic range:
  - 127dB (0dB gain, ±18V supplies)
  - 103dB (60dB gain, ±18V supplies)
- Tiny 4x4mm QFN16 package

THAT1570 Basic Circuit

- $G_{DIFF} = 1 + (R_A + R_B)/R_G$
- $G_{COMMON\text{-}MODE} = 1$



- Z_{IN} (Differential) = 2kΩ
- Set by R1 & R2

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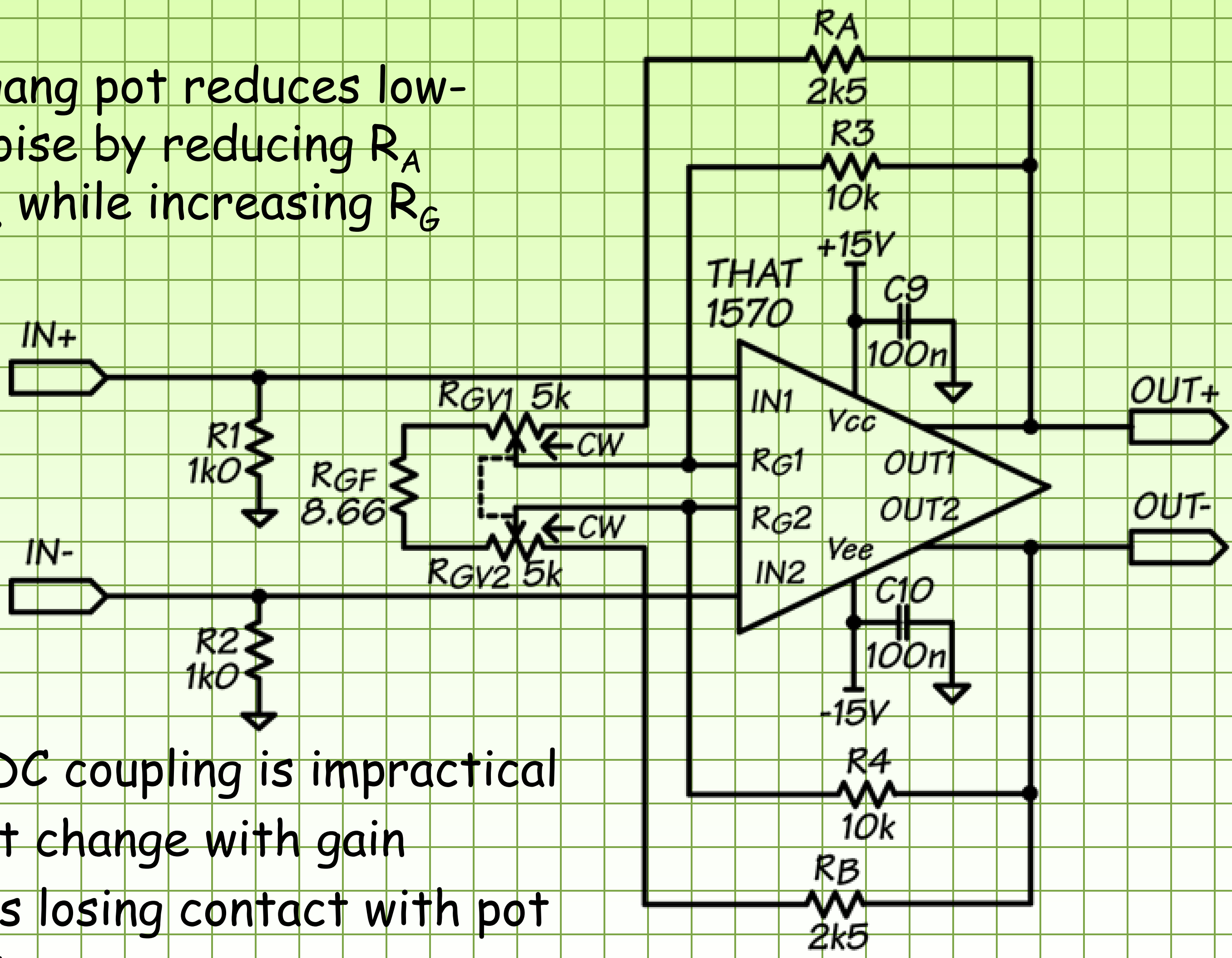
THAT1570 Improved Circuit

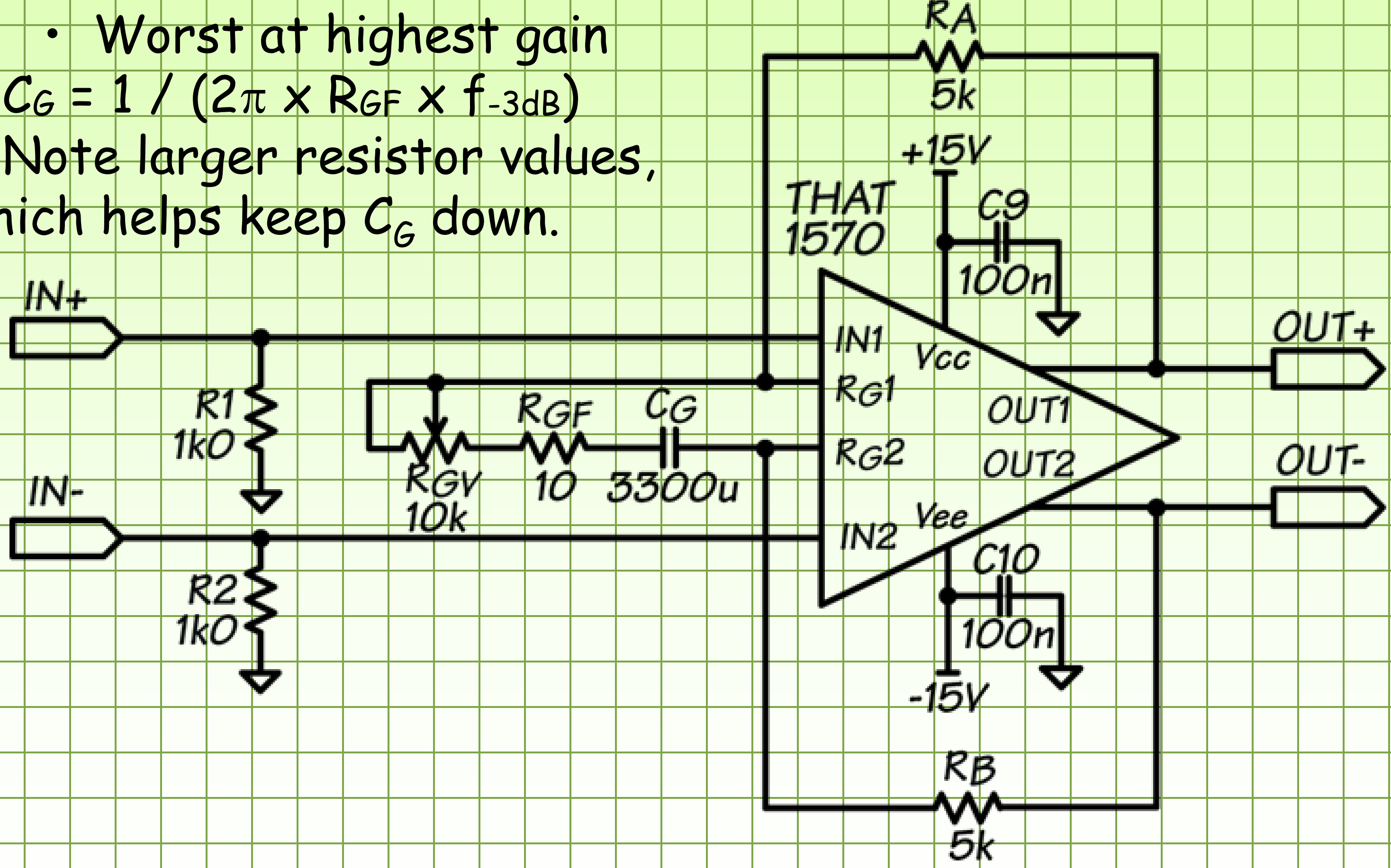
- Dual-gang pot reduces low-gain noise by reducing R_A and R_B while increasing R_G



- But… DC coupling is impractical
- Offset change with gain
- Wipers losing contact with pot tracks

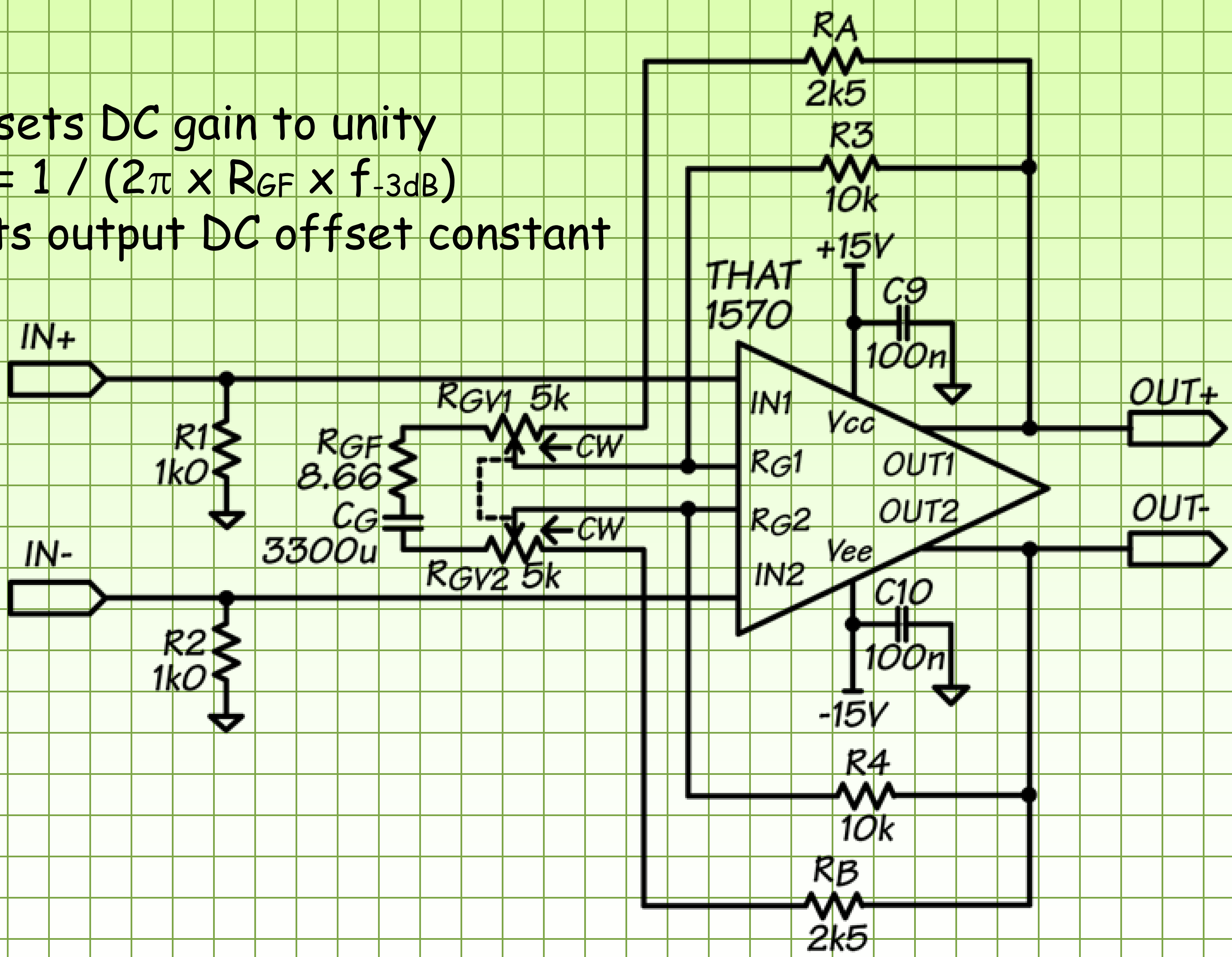
AC-Coupling R_G Addresses DC Offset

- C_G sets DC gain to unity
- Causes LF rolloff
    - Worst at highest gain
- $C_G = 1 / (2\pi \times R_{GF} \times f_{-3dB})$
- Note larger resistor values, which helps keep C_G down.

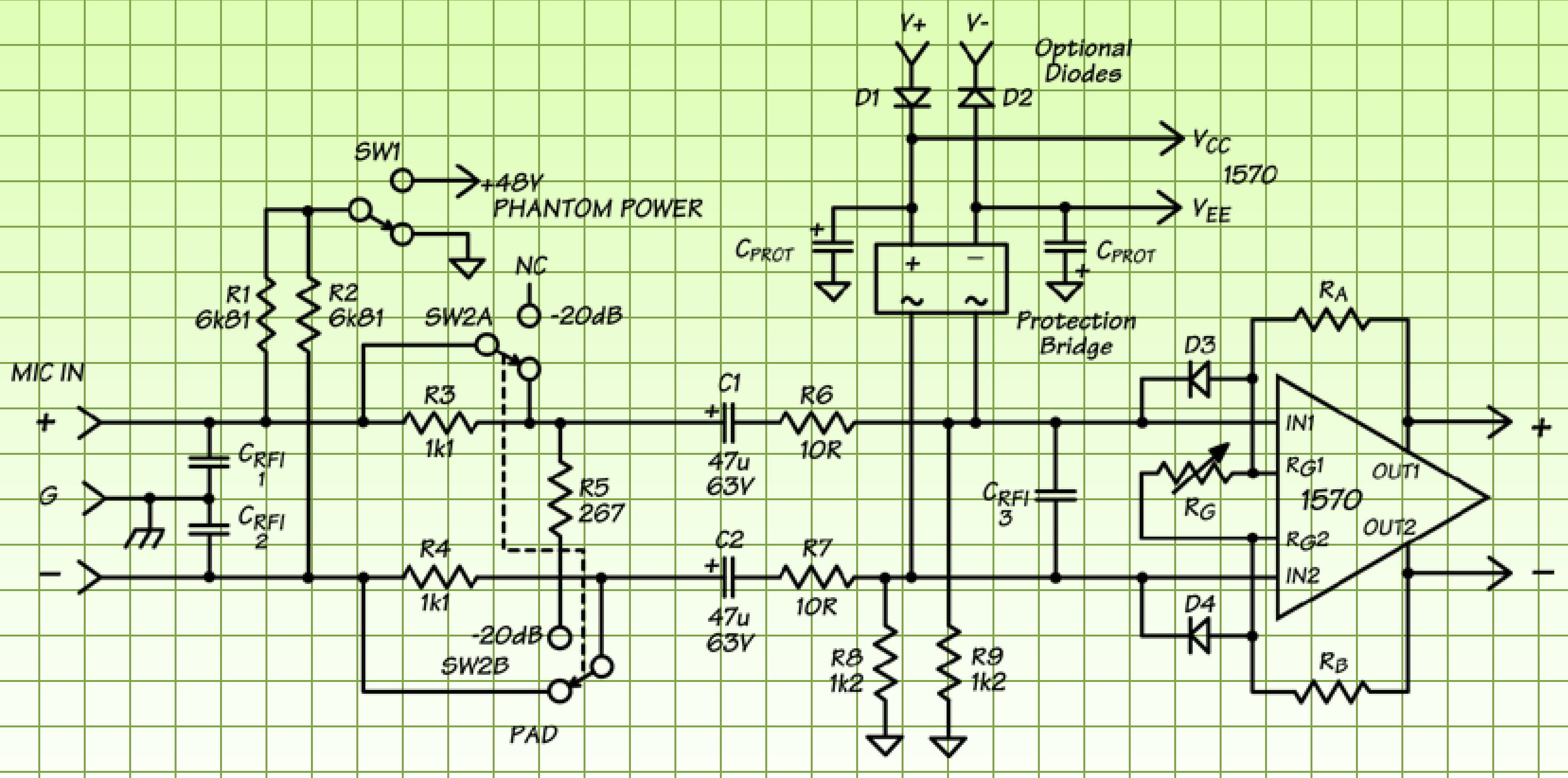


AC-Coupling In Dual-Gang Circuit

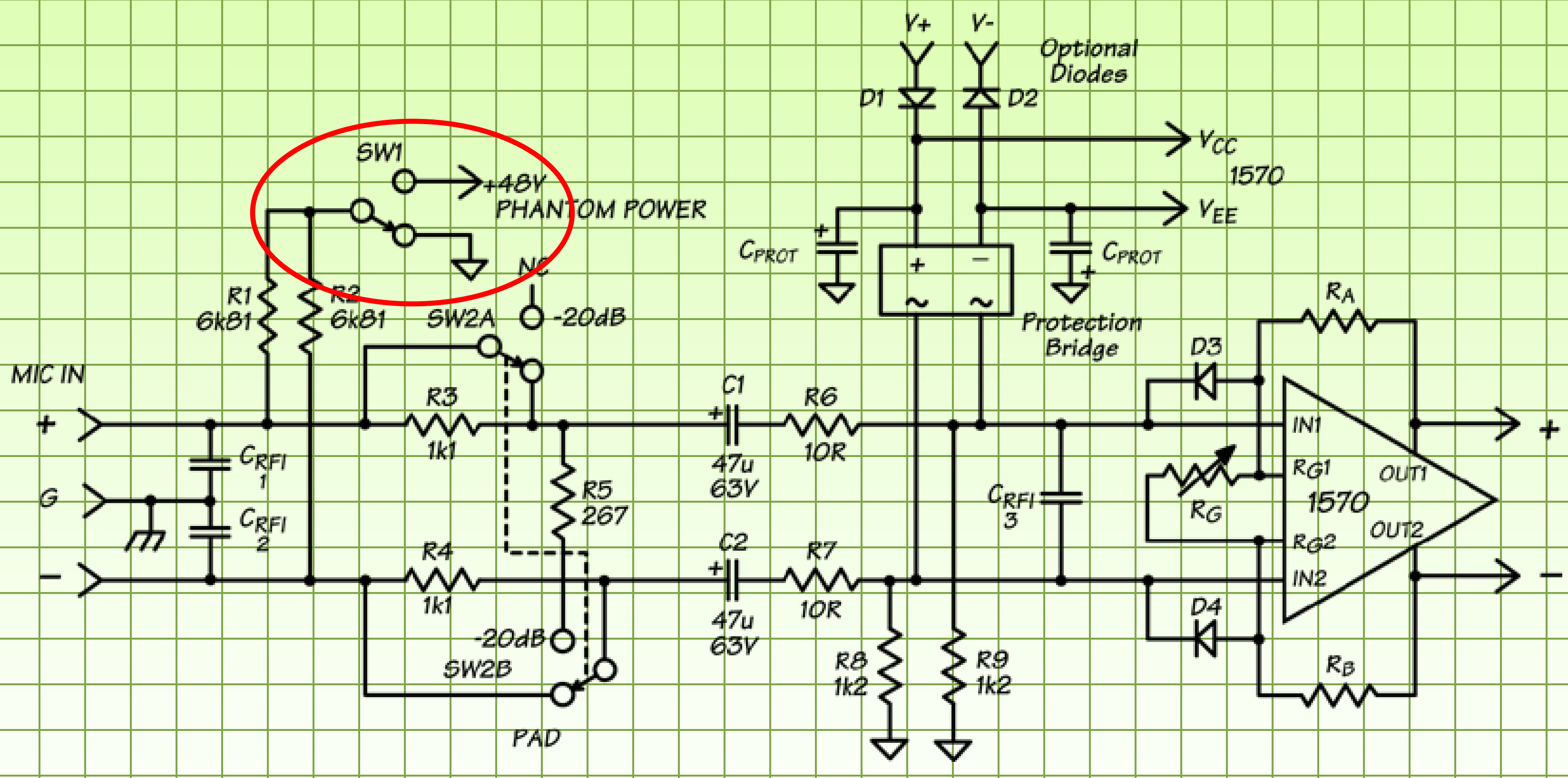
- C_G sets DC gain to unity
- $C_G = 1 / (2\pi \times R_{GF} \times f_{-3dB})$
- Sets output DC offset constant



"Real" Microphone Preamp Circuit



Phantom Power Switching

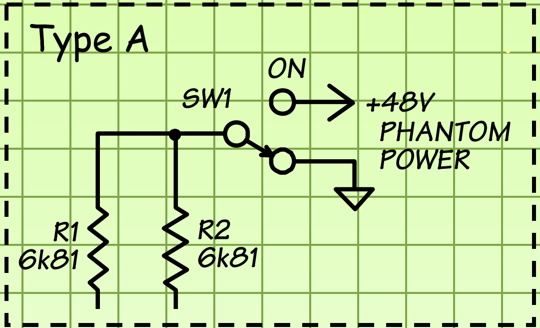


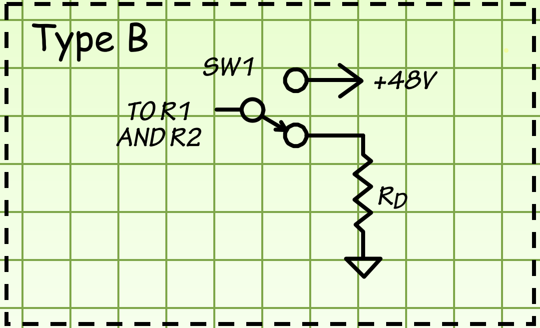
Phantom Power Switching

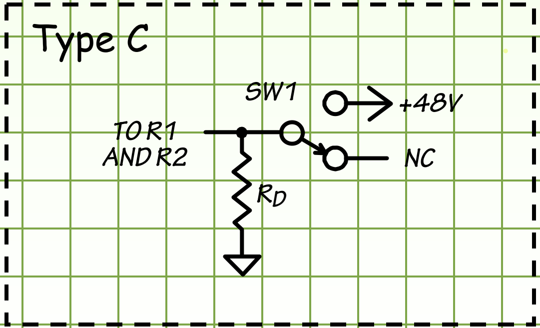
TYPE A
- R1 and R2 always in circuit
- Maintains constant Z_{IN}
- Differential Zin is R1+R2||R8+R9

TYPE B
- Higher Z_{IN} when phantom is off
    - R8+R9 only
- Useful when one mic feeds >1 preamp
- Longer discharge time constant

TYPE C
- Same Z_{IN} as Type B, but
- Burns more power
- Shorter discharge time

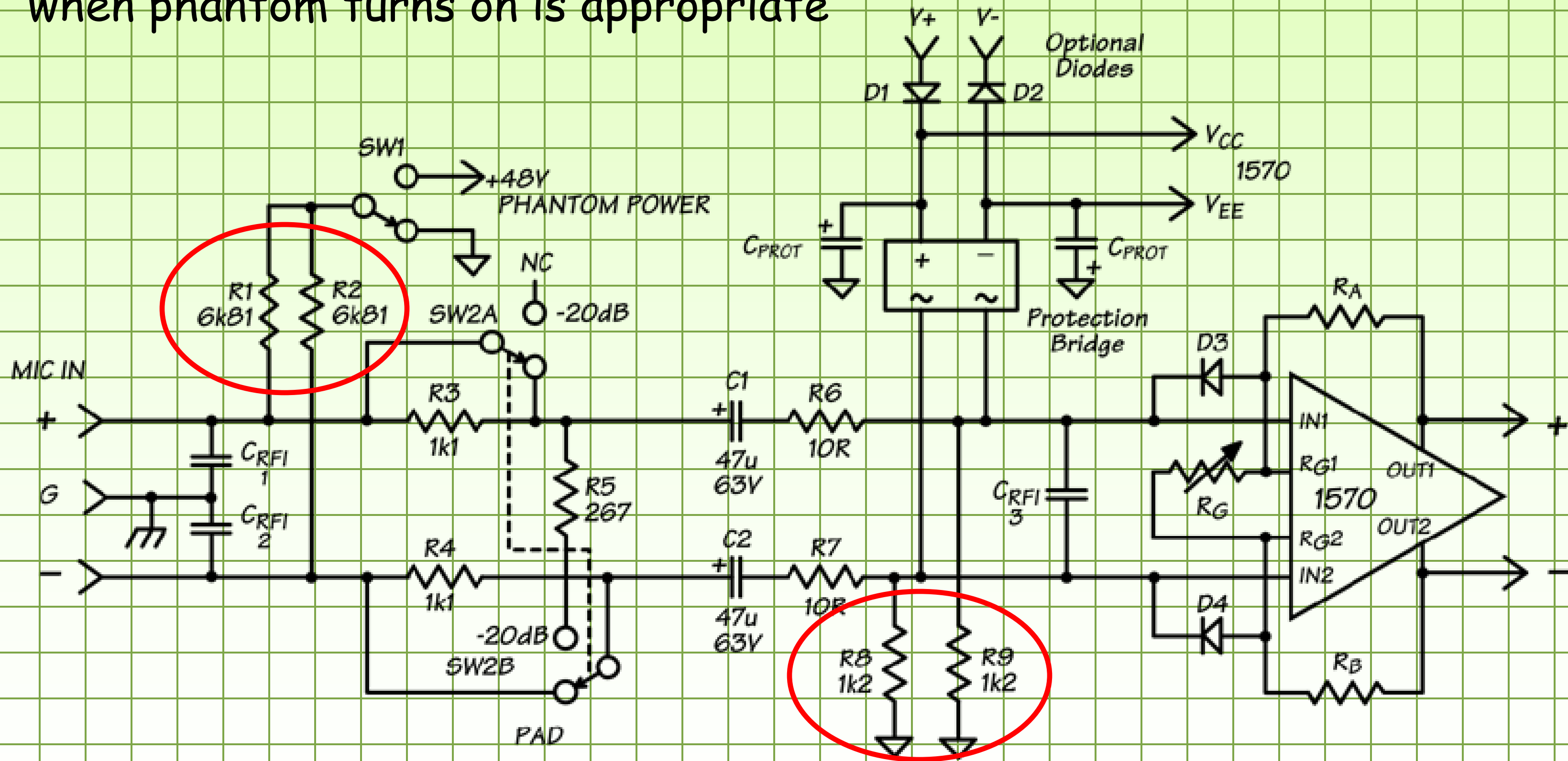




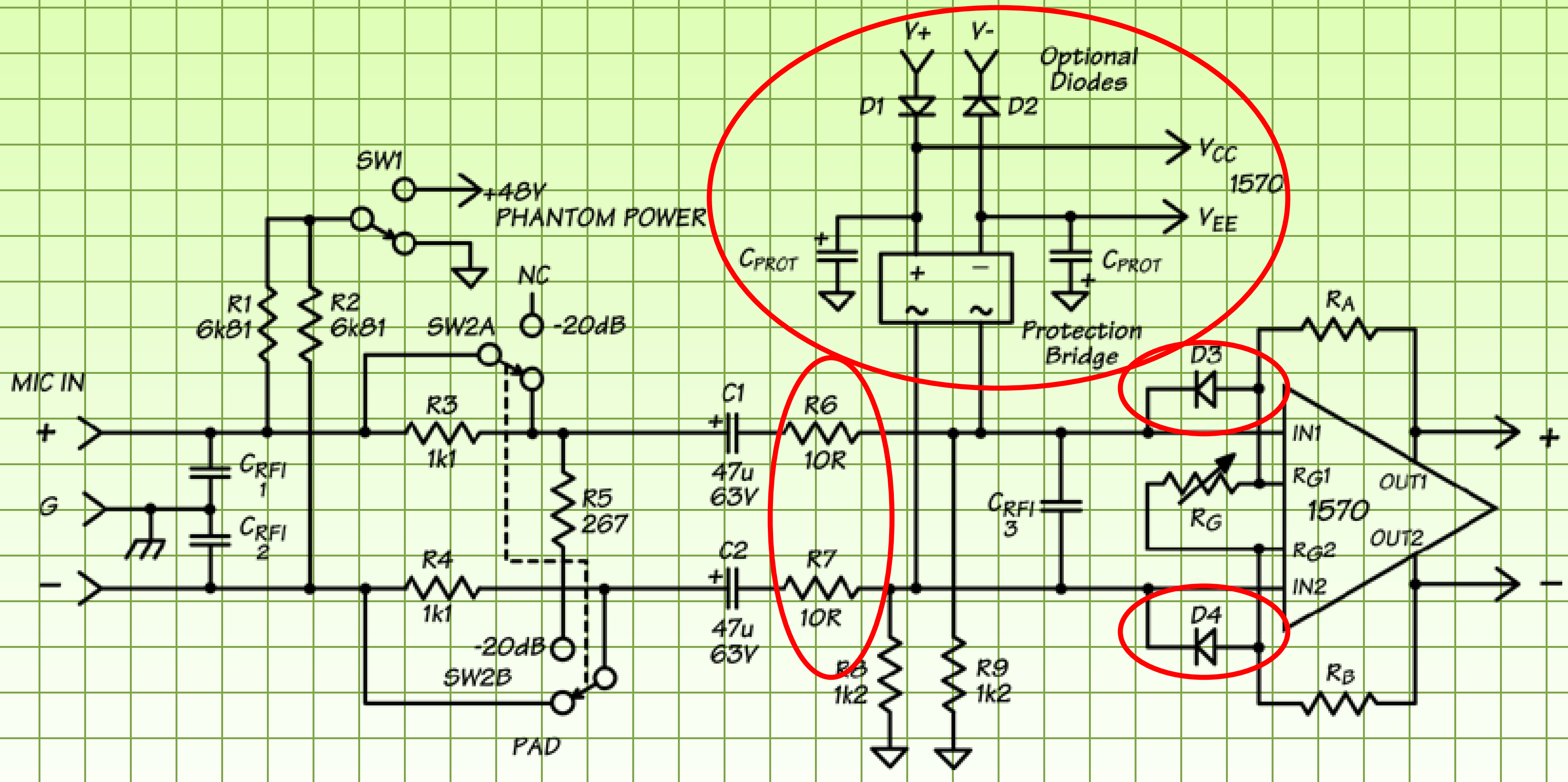


Phantom Power Start-up

- The phantom power-on transient (0 to +48V) is divided by input bias resistors R8 & R9 (1k2) working against R1 & R2 (6k81).
- The inputs jump by ~ 7.2V, which won't damage the 1570
- But, it's a pretty big thump, so muting when phantom turns on is appropriate



Phantom Power Protection

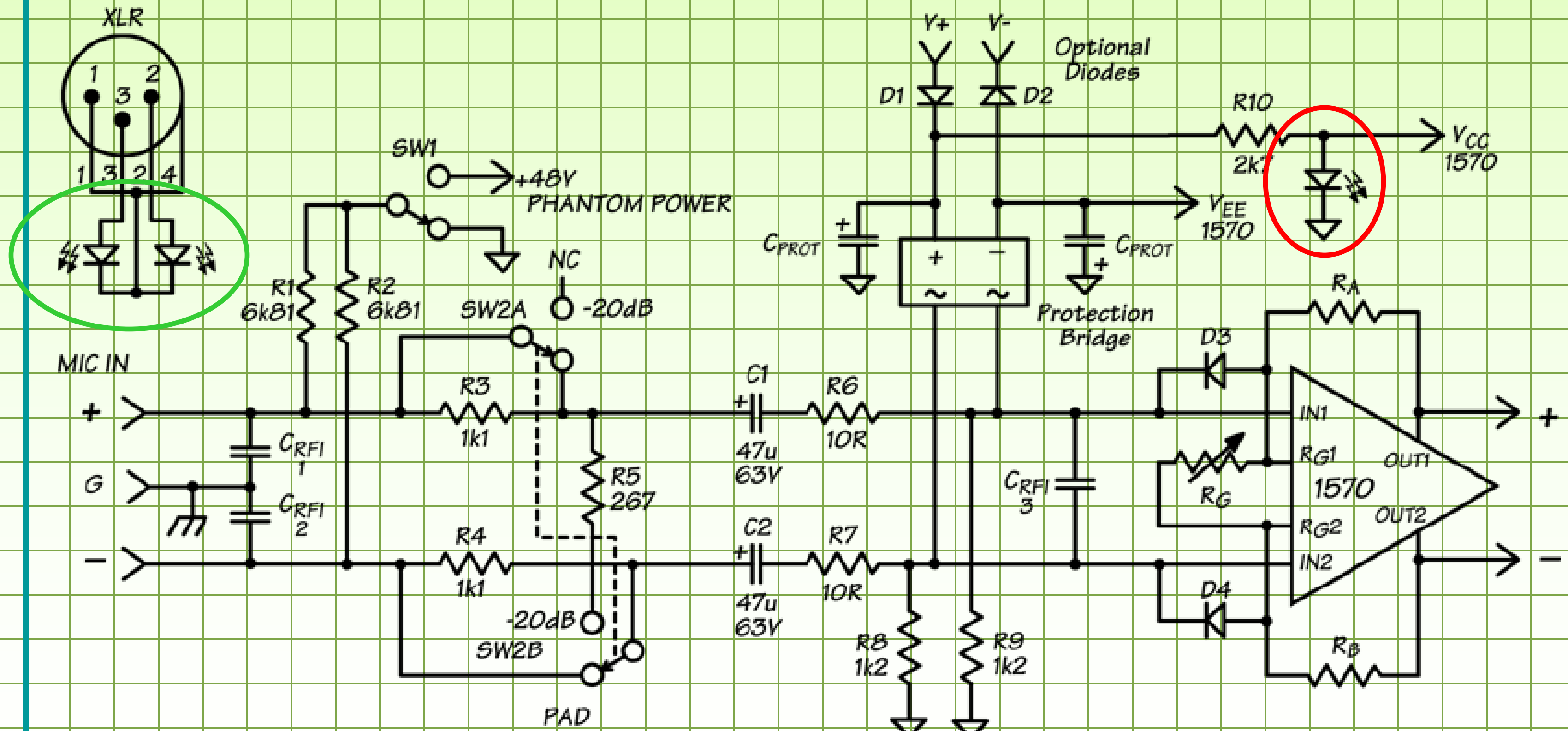


Phantom Power Faults

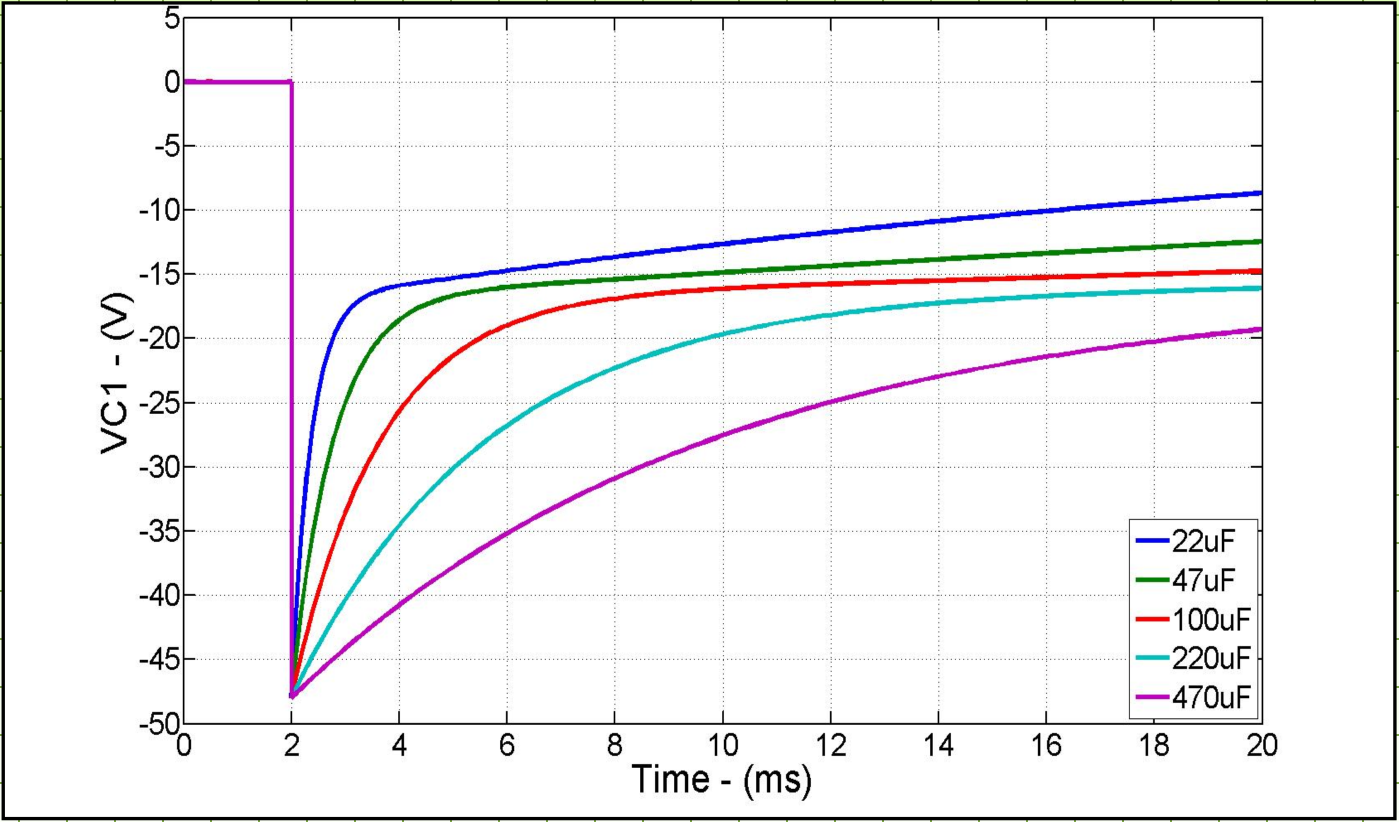
- Shorting input pins with phantom turned on
  - C1 & C2 start charged to 48V
  - Positive end of C1, C2 connect to ground
  - Negative end of C1, C2 driven to -48V!
- The shorting sequence can vary
  - "Single-ended": One input to ground
  - "Common-mode": both inputs to ground simultaneously
  - "Differental: One input to ground, then the other
  - Differential is worst
- Big currents flow as C1, C2 discharge
  - Currents over 3 ***amperes*** flow in the capacitors
- See "Phantom Menace Returns": Sunday 12:30pm, Session P12

Phantom Faults: How Bad Can It Be?

- Green LEDs on XLR
  - Create phantom fault
  - Indicate magnitude of current
- Red LED on positive supply
  - Mounted to circuit board
  - Monitors supply voltage

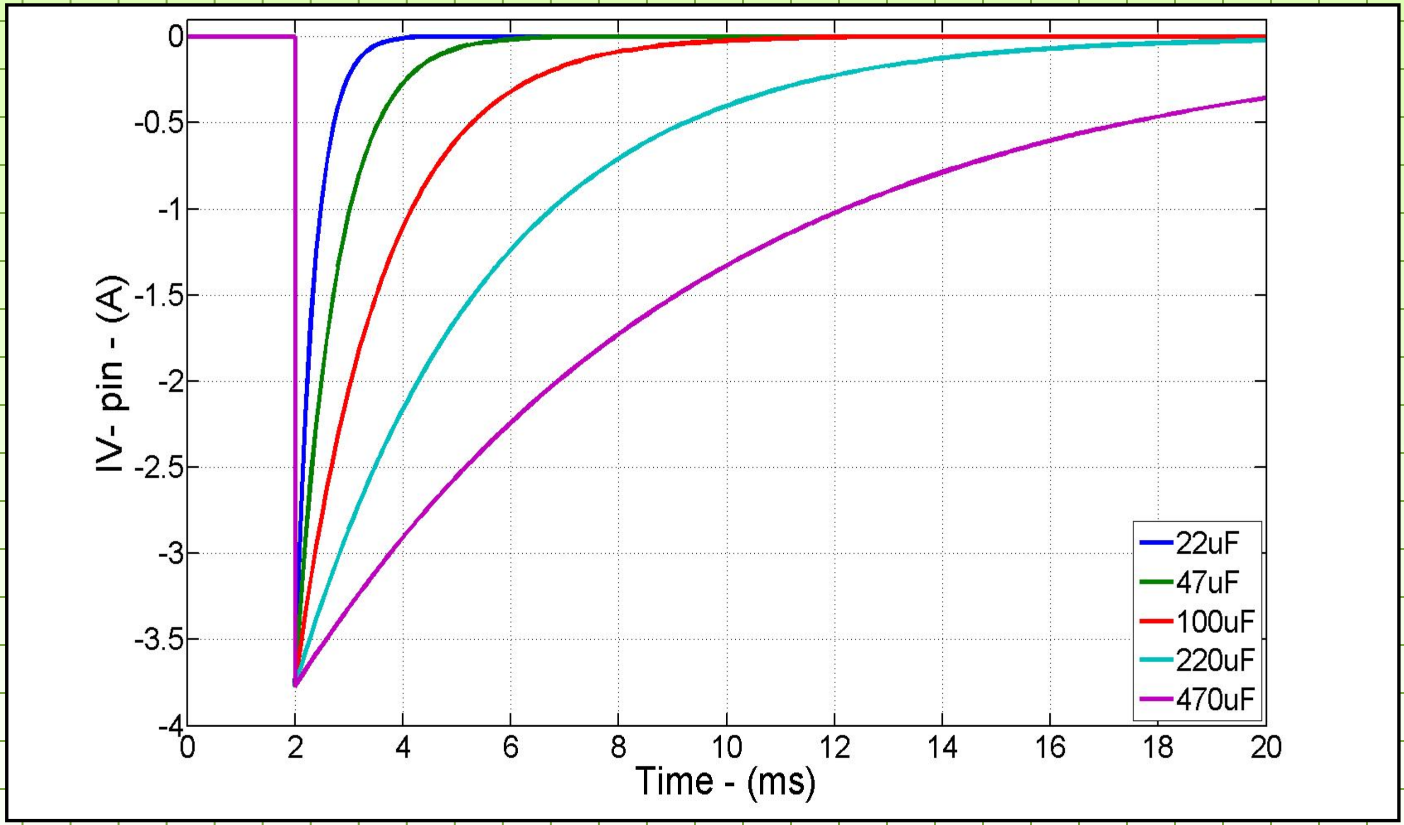


Phantom Power Fault Voltage



Voltage waveform at IC inputs during a common-mode fault.
Note **-48V** peak!

Phantom Power Fault Current



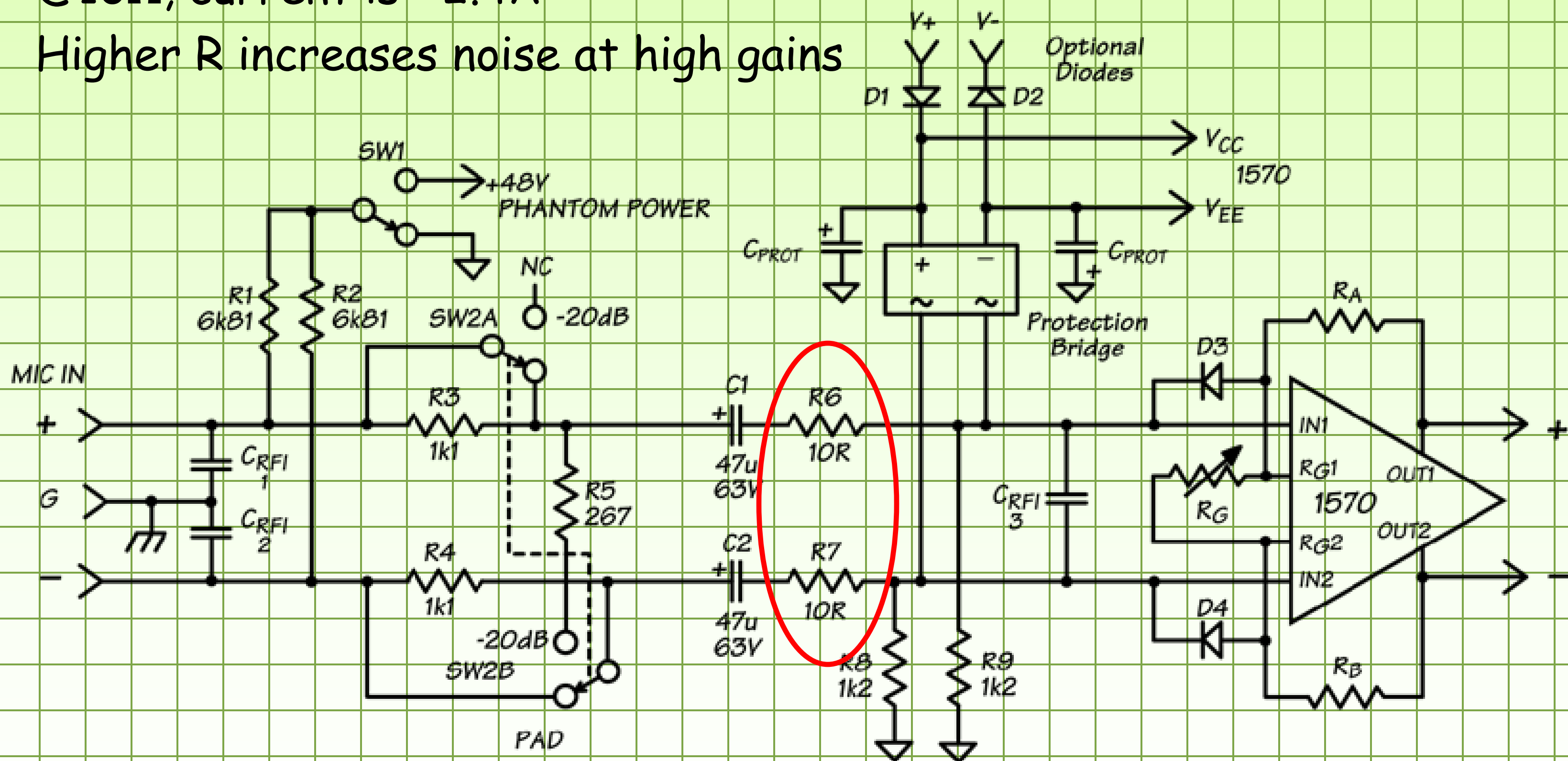
The current flows through the IC and out the negative supply pin.
It can easily exceed ***3 Amperes*** !

Protecting Against Phantom Power Faults

- Limit the current with small resistors
  - Can increase high-gain noise
- Steer the current around the IC
  - Input diodes steer current away from internal protect diodes
    - This current varies with gain setting
  - Diode bridge dumps current to rails
- Consider impact on supply rails
  - Minimize transient with capacitance
  - Isolate preamp rails from others

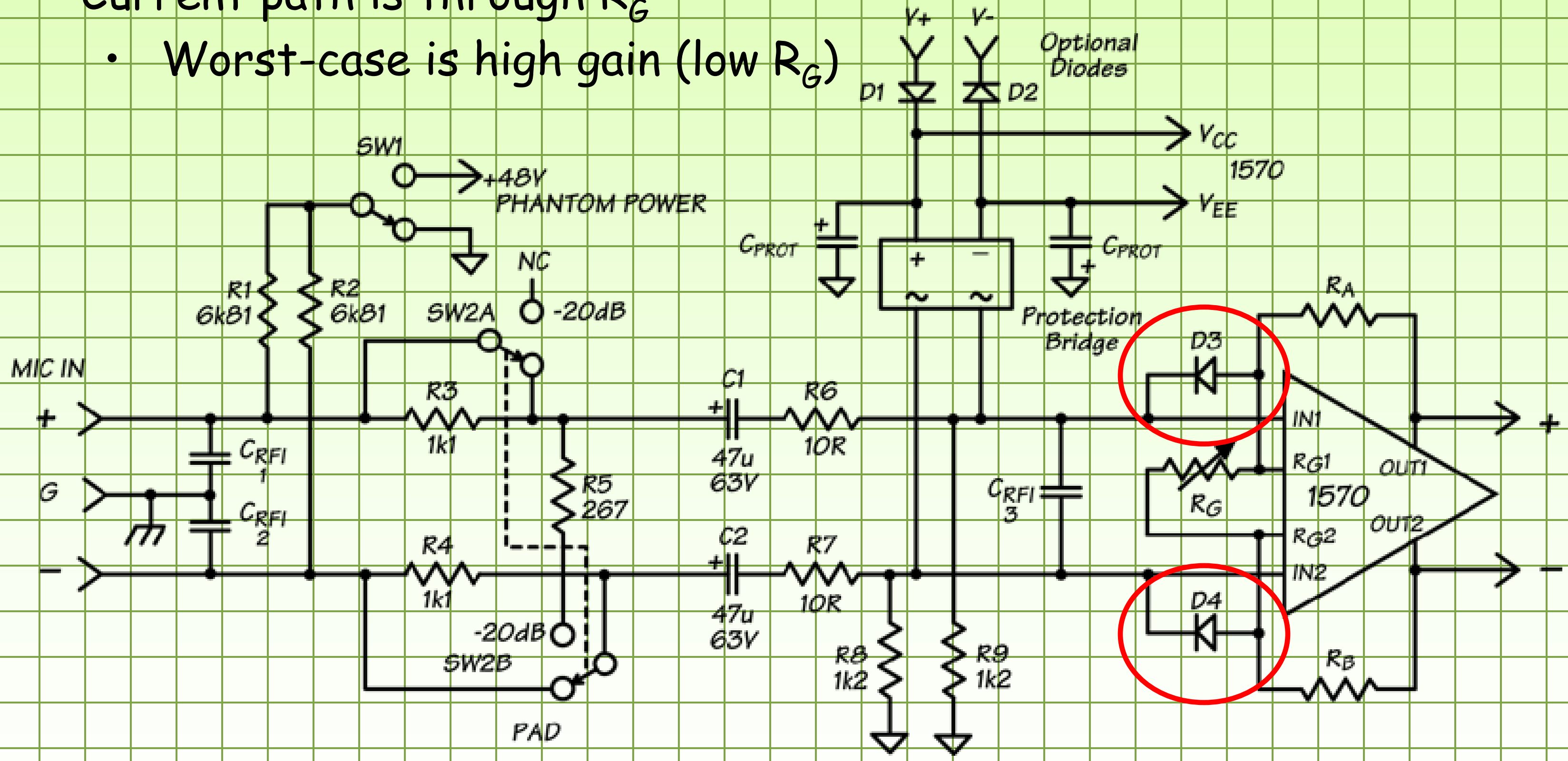
Phantom Fault Current Limiting

- R6 and R7 limit the current
- @10Ω, current is ~2.4A
- Higher R increases noise at high gains



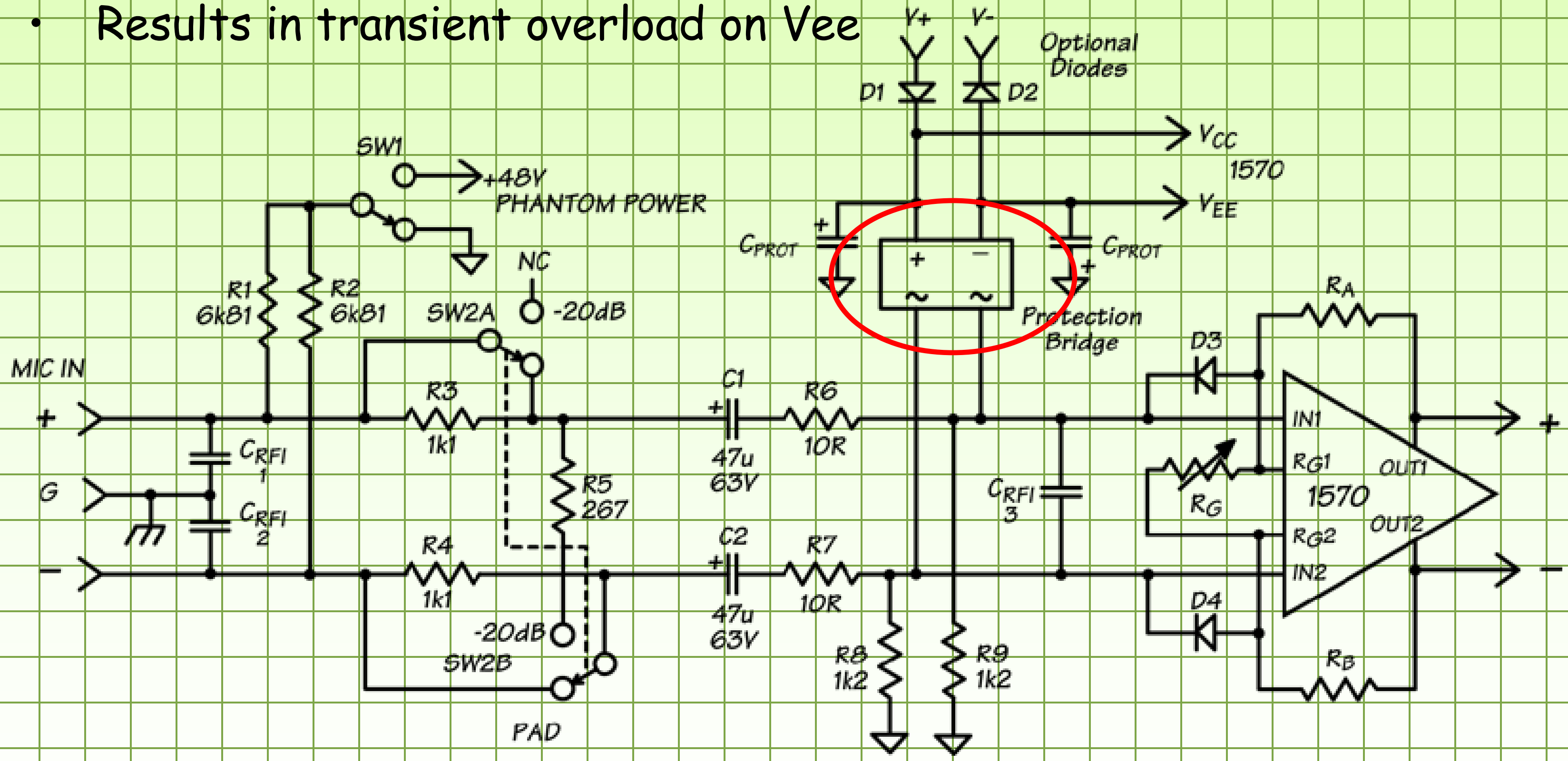
Phantom Power Protection

- D3 and D4 route current around the IC's input protection diodes
- Current path is through R_G
  - Worst-case is high gain (low R_G)



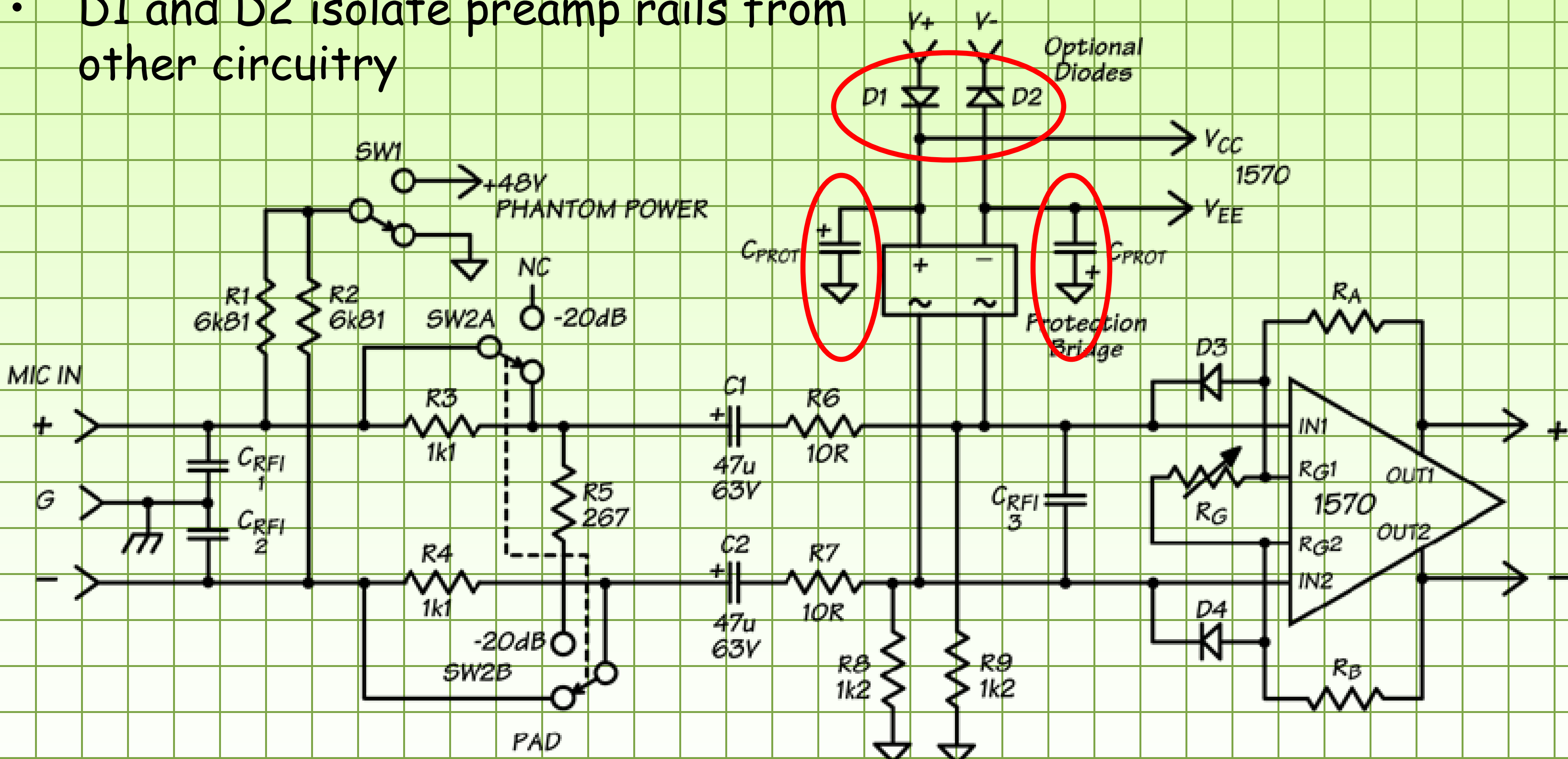
Phantom Power Protection

- Bridge steers current to the supply rails (mostly negative side)
- Results in transient overload on Vee



Phantom Power Protection

- C_{PROT} absorbs transient
  - Must be large to be significant
- D1 and D2 isolate preamp rails from other circuitry



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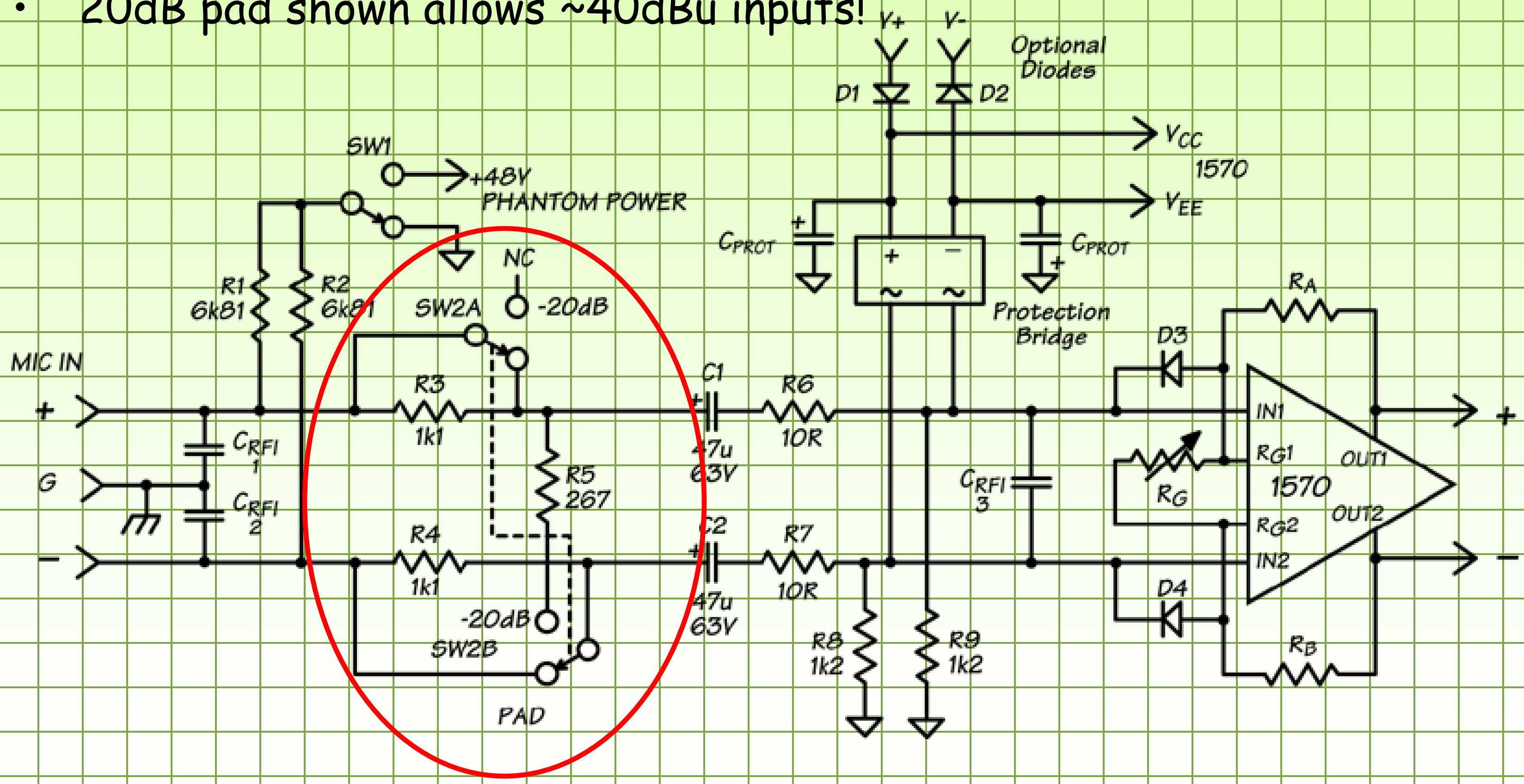
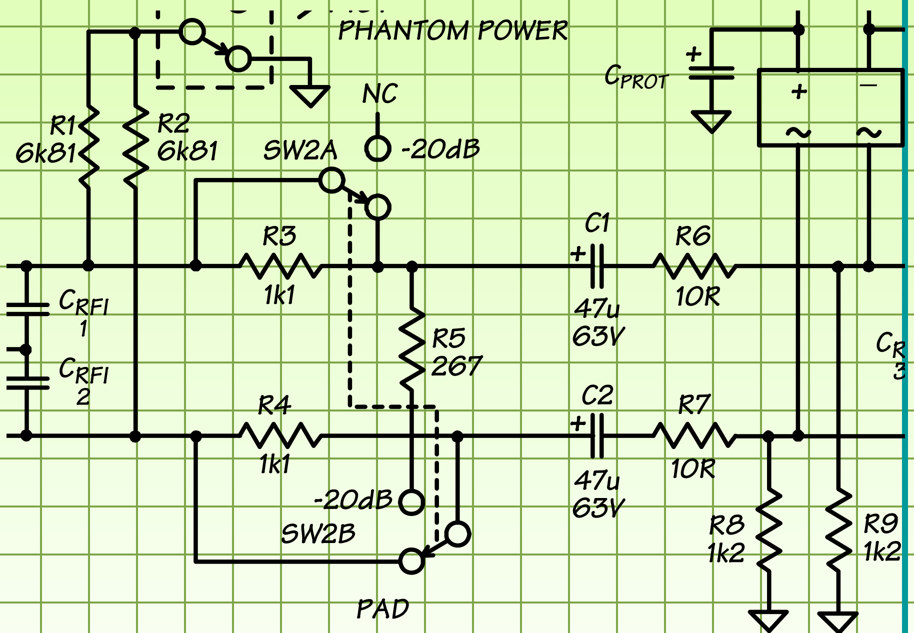
Microphone Input Pads

- Pad allows preamp to accept larger inputs
- Needed if input signal will exceed supply rails
- 20dB pad shown allows ~40dBu inputs!



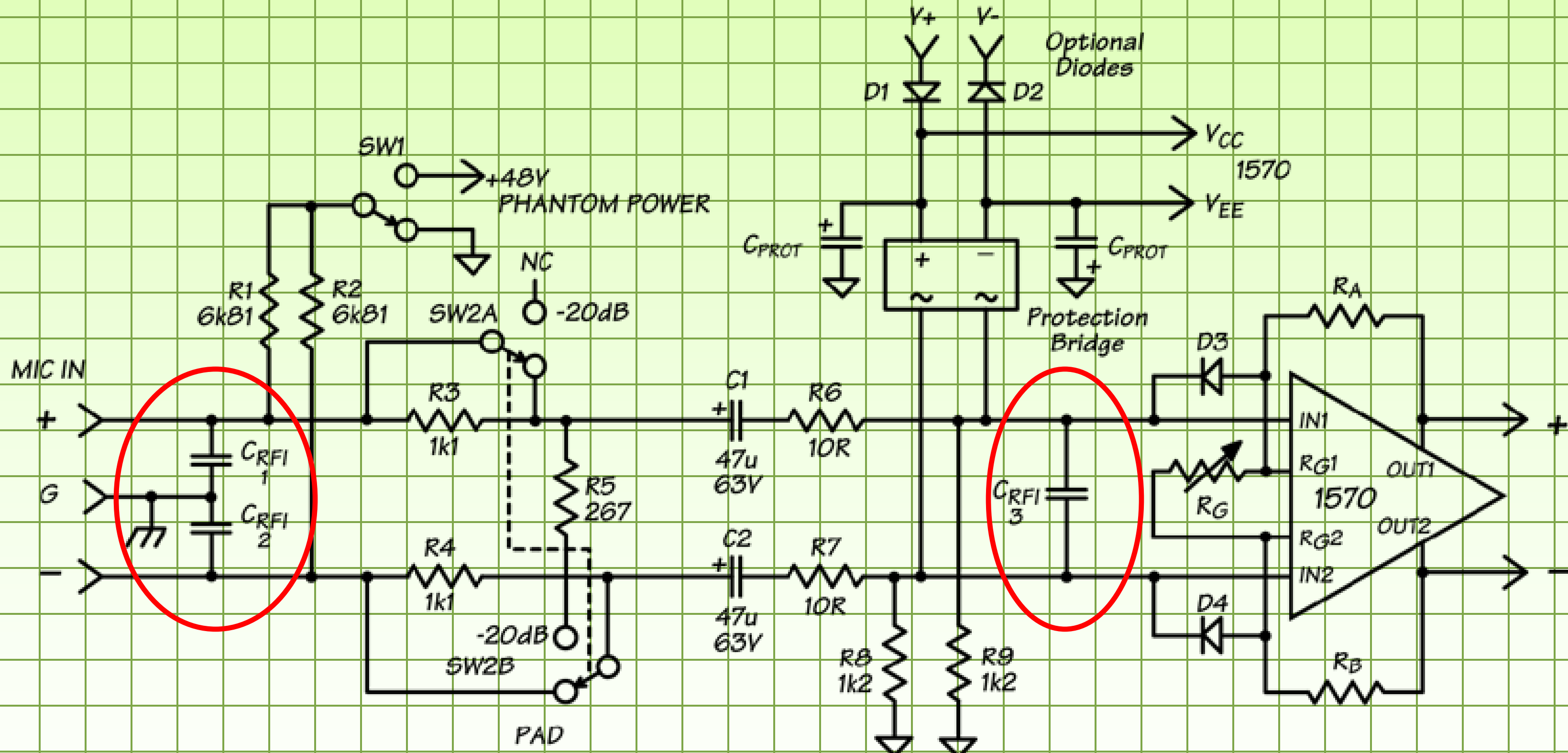
Microphone Input Pads

- U-pad design for constant input impedance
  - Same Z_{IN} with pad as without: ~ 2kΩ
  - U-pad prevents degrading CMR
- 20 dB attenuation shown
  - 20dB more headroom
  - Other levels are possible
- Little sacrifice to noise floor and dynamic range
  - Better noise, less headroom with less attenuation
- Maintains low source impedance to IC inputs ~240Ω
  - 1570, 1512, & 1510 are optimized for low noise with low source impedances



RFI Protection

- RFI protection is required in any practical design



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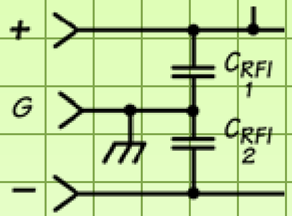
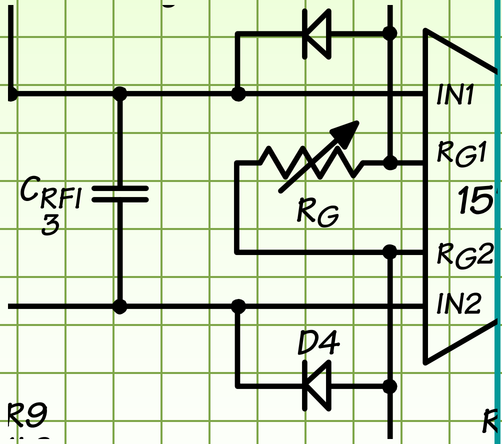
RFI Protection

- $C_{RFI}1$ and $C_{RFI}2$ stop RF at the enclosure input
- Must be located right at the input connector
- Affects differential *and* common-mode RFI



- $C_{RFI}3$ reduces differential RFI
- Affects incoming and internally generated RFI:
  - Clocks
  - Switching power supplies
  - Other digital signals
- Should be located right at the IC input pins



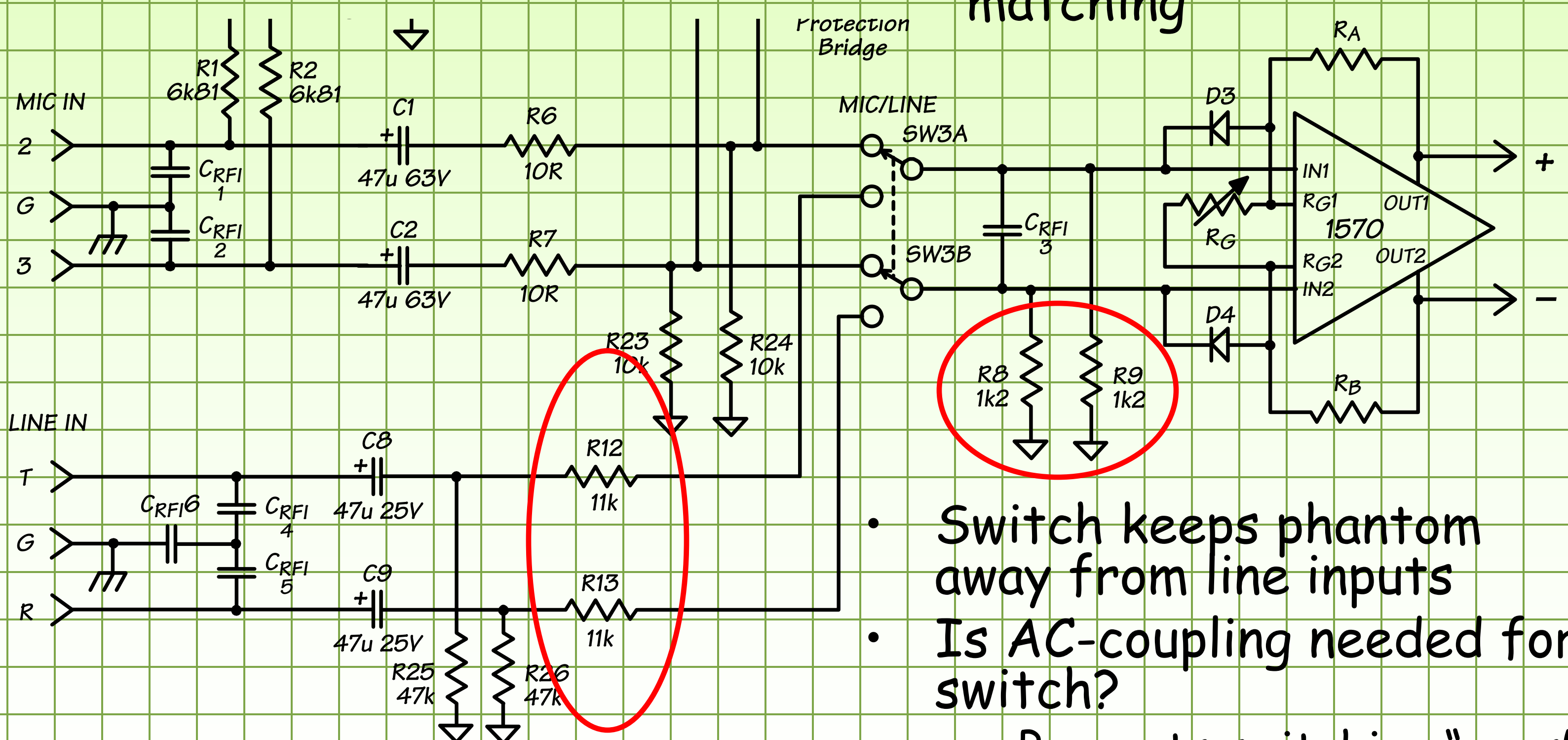
Line Inputs

- Should have higher Z_{IN} than Mic inputs
  - >=10kΩ ?
  - Can switch, use combo connector, or let user select between two connectors
- For variable gain
  - Can use mic preamp to control gain
  - Pad input and increase Z_{IN}
  - Attenuation and Z_{IN} are related
- For fixed gain
  - Can switch after mic preamp

Variable-Gain Line Inputs

- R12 & R13 form an "L-pad" attenuator with R8 & R9
- Zin = R12+R13+R8+R9 || R25+R26 = 20k
- 20dB attenuation shown

- L-pad attenuation differs with source
  - Differential vs single ended
- CMR depends on resistor matching



- Switch keeps phantom away from line inputs
- Is AC-coupling needed for switch?
  - Prevents switching "pops"

Variable-Gain Line Input Performance

Specs for the proposed LINE input, 20 dB attenuation,
R_{12} & R_{13} = 11 kΩ, Zin = 20 kΩ (R_A = R_B = 2.21 kΩ)

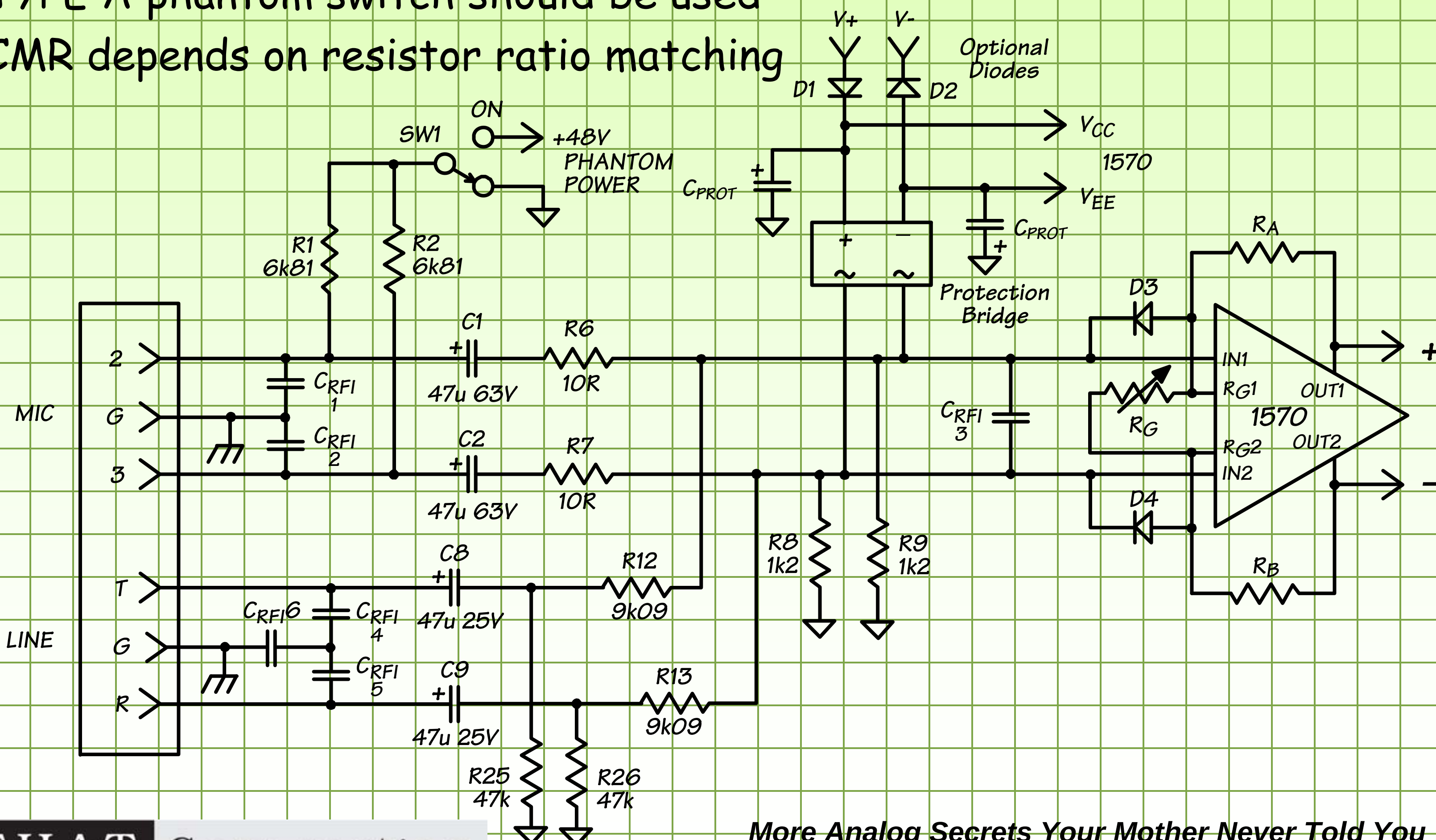
System Gain (dB)	IC Preamp Gain (dB)	RG (Ω)	Maximum Input Signal (dBu)	Input Referred Noise (dBu)	Dynamic Range (dB)
0	20	487	26.6	-96.7	123.3
-3	17	732	29.6	-96.2	125.8
-6	14	1,100	32.6	-95.5	128.1

Specs for the proposed LINE input, 12 dB attenuation,
R_{12} & R_{13} = 3.57 kΩ, Zin = 10 kΩ (R_A = R_B = 2.21 kΩ)

System Gain (dB)	IC Preamp Gain (dB)	RG (Ω)	Maximum Input Signal (dBu)	Input Referred Noise (dBu)	Dynamic Range (dB)
0	12	1,470	26.6	-103.6	130.2
-3	9	2,430	29.6	-102.3	131.9
-6	6	4,420	32.6	-100.7	133.3

Variable-Gain Line In with Combo Connector

- "Combo" connectors don't need MIC/LINE switching
- Same 20 dB attenuation (different R12 and R13)
- TYPE A phantom switch should be used
- CMR depends on resistor ratio matching



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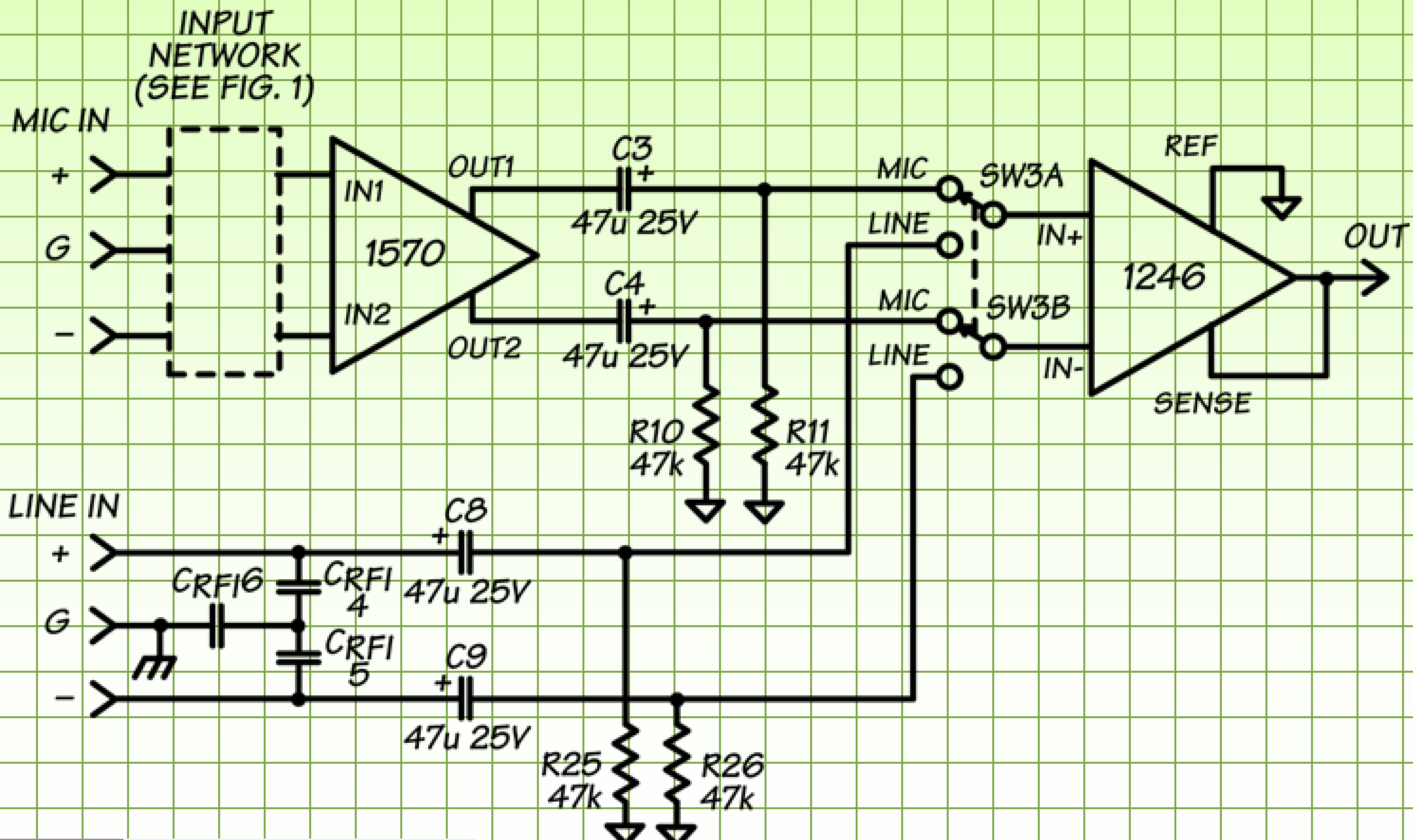
Fixed-Gain Line In

- 6 dB attenuation (1246)
- Requires coupling capacitors (C3, C4, C8, and C9)
- Great CMR (1246)

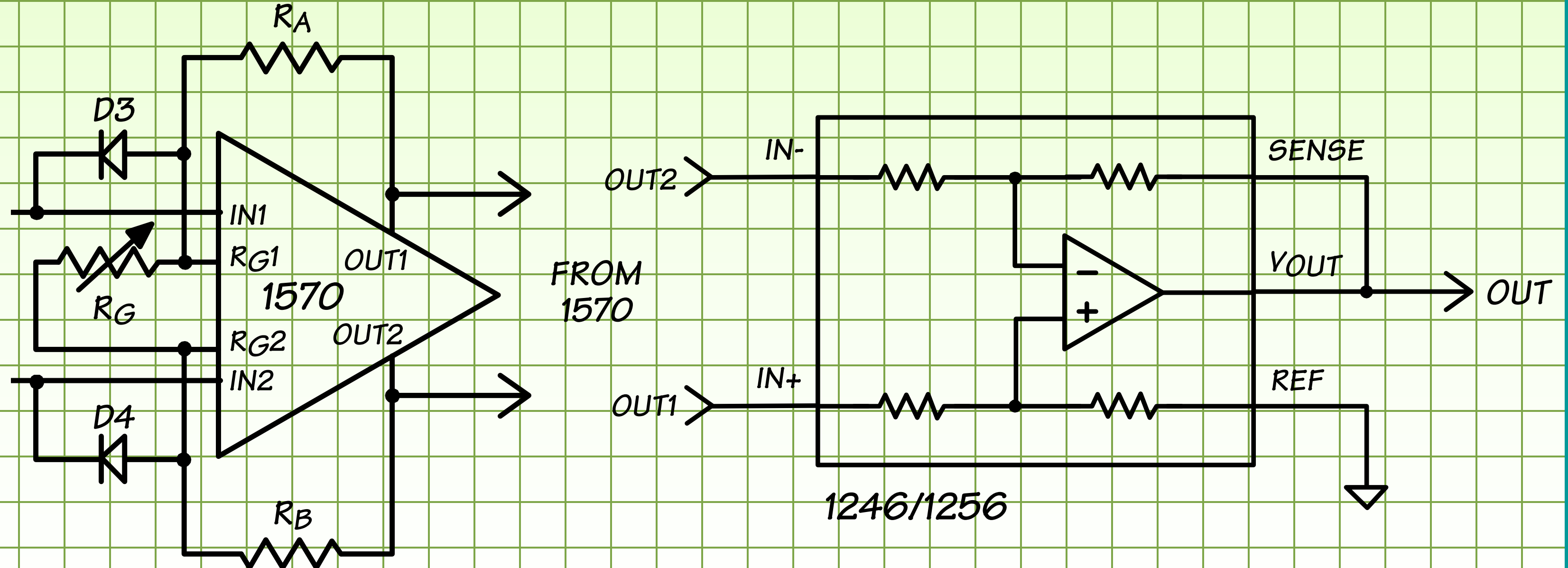


Output Stages

- Differential mic amp (1570) has unity common-mode gain
- Common-Mode Rejection = differential gain
  - 0dB CMR @ 0dB gain
  - 60dB CMR @ 60dB gain
- Output stage must provide CMR
- Tight component match will be important

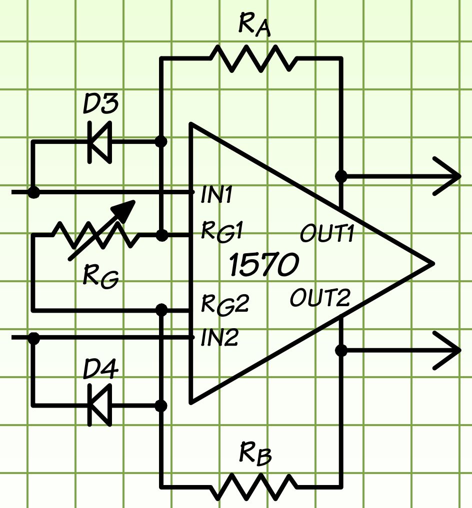
Output Stages (Single Ended)

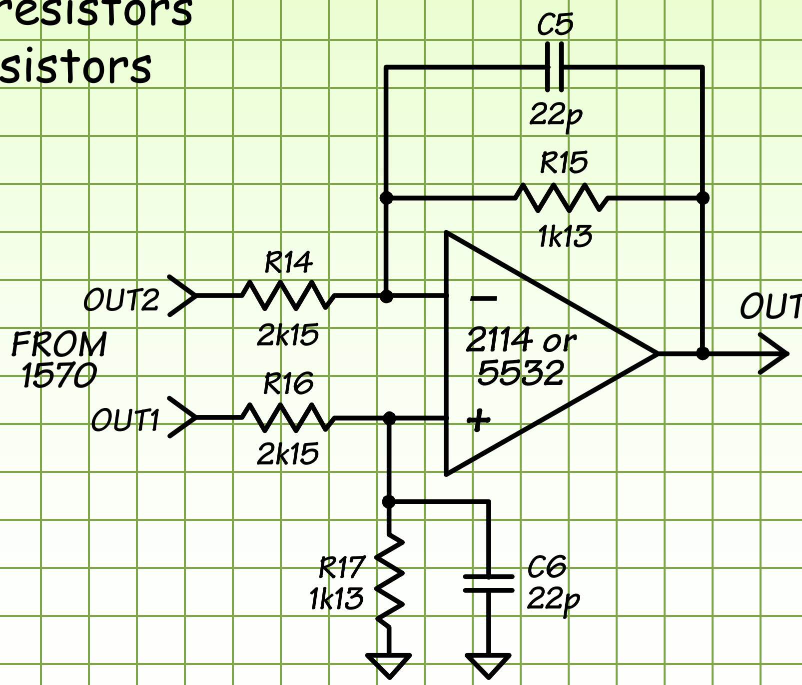
- One-part solutions
  - THAT1246 (dual: 1286) - Great common-mode rejection (~90 dB)
  - THAT1256 (dual: 1296) - Good common-mode rejection (~50 dB)
  - System gain is 0 dB with +6 dB preamp gain (-6 dB with 0 dB preamp gain)
- Adds ~8 dB to the 1570 noise at minimum (-6 dB) gain ($R_A = R_B = 2.2\ k\Omega$; R_G = open)
- Added noise drops with gain: adds ~4 dB noise at 0 dB gain



Output Stages (Single-Ended)

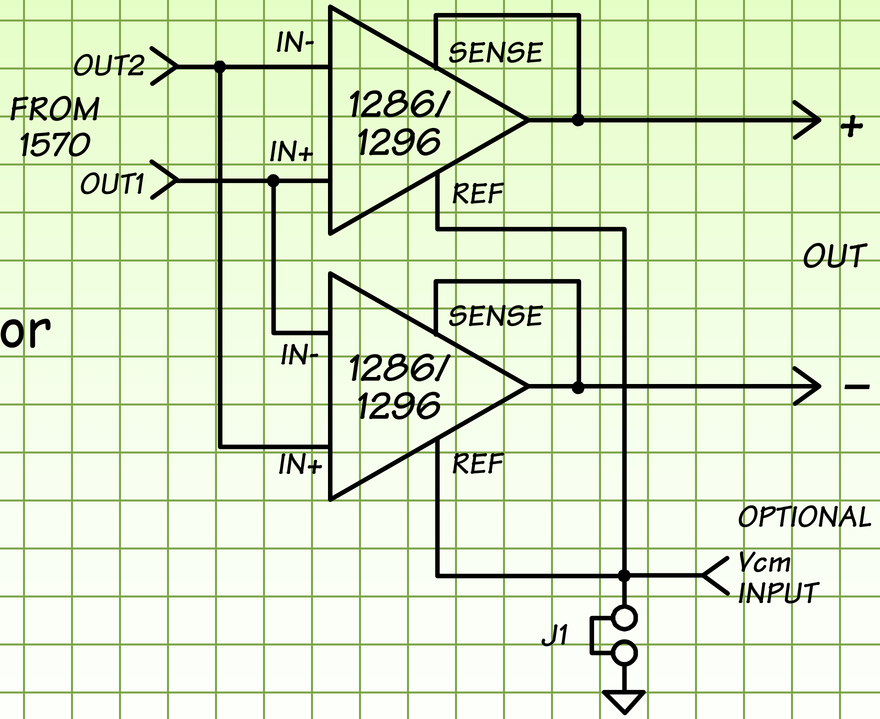
- To match 1570 noise, must use (much!) quieter opamp and (very) low-value resistors
- 5532 (single: 5534) or 2114 (both duals) are good choices
- -5.6 dB gain shown matches 1570/5171 minimum preamp gain
- The 2114 adds ~2.5 dB to the 1570 noise floor with 0dB system gain
  - Additional noise is negligible for gains above ~7.5 dB
- CMR will be limited compared to 1240/1250/1280/1290 options
  - 54 dB minimum, with 0.1% resistors
  - 34 dB minimum, with 1% resistors





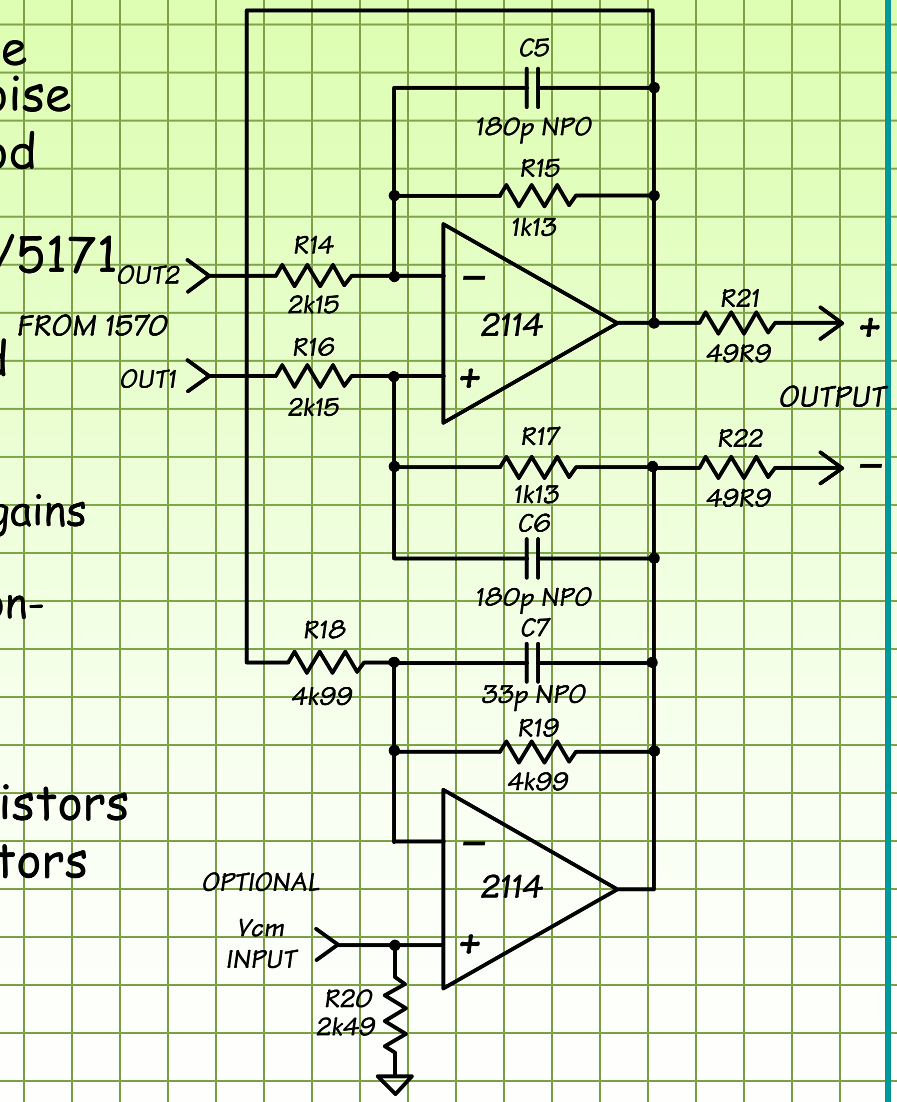
Output Stages (Differential)

- Good (1296) to great (1286) CMR
- 1286/1296 can drive loads below ~2 kΩ
- Compromises noise at low gains (like 1240/1250)
- Provides Vcm input for driving A/D converters
  - To maintain high CMR, ensure Vcm is driven by low source impedance
  - Requires low-Z attenuator between the 1268/1296 and the ADC input (optimizes noise & headroom)



Output Stages (Differential)

- Again, quieter opamp and low-value resistors better matches 1570 noise
- 5532 or 2114 (both duals) are good choices
- -5.6 dB gain shown matches 1570/5171 minimum preamp gain
- Same added noise as single-ended circuits
  - ~+2.5 dB with 0dB system gain
  - Additional noise is negligible for gains above ~7.5 dB
  - Noise of second 2114 is all common-mode
- CMR will be limited compared to 1280/1290 options
  - 54 dB minimum, with 0.1% resistors
  - 34 dB minimum, with 1% resistors
- Vcm doesn't require buffer
- C5 = C6 >> C7 for outstanding transient response



Comparing THAT Analog Mic Preamps

	1570	1512	1510	
Vcc/Vee, max	±18	±20	±20	V
Icc/Iee, typ	±7.5	±6.0	±6.0	mA
Vinmax	28.7	30.3	24.3	dBu
BW, 40 dB gain	4.2	7.0	7.0	MHz
Slew Rate, typ	53	19	19	V/μs
THD+N, <30 dB	0.0003	0.004	0.0012	%
EIN, 60dB gain	1	1	1	nV/√Hz
EIN, 0 dB gain	18.5	34	57	nV/√Hz
Gain Range	0 to +70	-6 to 64	0 to +70	dB
Gain Equation	$1 + (R_A + R_B)/R_G$	$0.5 + 5\ k\Omega/R_G$	$1 + 10\ k\Omega/R_G$	V/V
Output	Differential	Single-ended	Single-ended	-----

Conclusions

- THAT 1570 is the quietest micpreamp
- External Rf resistors and differential output expand possibilities
- Real-world use requires extra protection to the IC
- Perfect match to the THAT5171
- Look forward to DN140! Will be soon available for download!

Bonus: THAT Corp Legendary Support

- THAT is focused on ICs for pro audio
- THAT engineers have many decades experience in pro audio
- THAT routinely advises customers on design/PCB layout.
- Please let us help you!

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